REMOTE SENSING APPLICATIONS IN FORESTRY

A report of research performed under the auspices of the

FORESTRY REMOTE SENSING LABORATORY,
SCHOOL OF FORESTRY AND CONSERVATION
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

A Coordination Task Carried Out in Cooperation with
The Forest Service, U.S. Department of Agriculture

For

EARTH RESOURCES SURVEY PROGRAM
OFFICE OF SPACE SCIENCES AND APPLICATIONS
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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REMOTE SENSING APPLICATIONS IN FORESTRY

INVENTORY OF NATIVE VEGETATION AND
RELATED RESOURCES FROM
SPACE PHOTOGRAPHY

by W12-996

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ABSTRACT

Work during the current report period was heavily involved in: (1) ground-truth support for the Apollo 9 mission and the S065 and High-flight experiments, (2) acquisition of specialized ground-truth and preliminary evaluation of multiseasonal photography as an aid to vegetation interpretation, (3) development and testing of a symbolic legend concept for use in photo interpretation and the annotation of mapped delineations, (4) initial field work on development of an ecological ground-truth classification that is essential to detailed, quantitative, image-relationship studies and to legend refinement at levels required in vegetational management decisions, and (5) demonstration of the feasibility of vegetational resource analysis by aerial photography subsampling at various scales from initial stratifications on space photography. This latter step permits the complete, quantitative characterization of space-photo images of naturally vegetated landscapes We were able, in addition, to resume work on multispectral linescan data near the close of the report period.

Varying phenology (seasonal development) of the species that predominate in each naturally vegetated ecosystem allows one to exercise a powerful recognition tool in the remote sensing of range and forest environments just as it does with agricultural crops. Color infrared sensing of these seasonal changes provides a mechanism for recoding the differences in plant development rates that are unique to each ecosystem. Some preliminary color densitometry studies suggest that it may be possible to recognize certain plant groupings from their near infrared reflectivity as recorded on carefully exposed and processed film.

A symbolic legend concept was tested. It embodies a numerator/denominator format treating broad classes on the left and progressing stepwise to refined classes on the right. The symbolic legend was found especially suited

to a multistage subsampling concept where space photography is used as the first stage. The symbolic legend is a non-connotative, numerical, closed-legend system that treats vegetation and land use in the numerator and physical environmental features in the denominator. The symbolic legend is an effective shorthand for the photo interpreter and especially adaptable to computerization.

The small amount of work accomplished with multispectral linescan data for rangeland ecosystems was very encouraging. Based on manual comparisons of the better, first iteration statistics on training samples developed for us by LARS, it appears highly probable that many specific rangeland ecosystems can be recognized by LARSYSAA, digital analysis of data. In addition, it appears that certain broad classes of forage use levels may be automatically recognized from multispectral linescan data of variously grazed crested wheatgrass seedings.

Aerial photography subsampling appears to be an excellent technique for quantifying the kinds and amounts of native vegetational resources and land uses represented by space images. When subsampling aircraft flights can be planned from stratification of space photography and for the particular requirements of vegetational resource analysis, high gains seem probable in minimizing cost and increasing the efficiency with which one may obtain statistics for planning the use and development of man's environment. By adjustment of sampling intensity at the appropriate photo scales, many facts for decisions about management and specific action programs may also be obtainable where highly detailed maps of the complete management area are not required.

ACKNOWLEDGEMENTS

This research was performed under the sponsorship and financial assistance of the National Aeronautics and Space Administration for the Earth Resources Program in Agriculture/Forestry, Contract Number R-09-038-002.

Appreciation is expressed to Robert N. Colwell and his group at the Forestry Remote Sensing Laboratory, Berkeley, California. Steven J. Daus and Claire M. Hay, employees of that lab, helped obtain three series of ground photographs as a part of the multiseasonal imagery study.

This research has also been conducted in cooperation with Robert C. Heller and Richard S. Driscoll of the U. S. Forest Service.

Appreciation is also expressed to Raymond M. Turner, U. S. Geological Survey, Tucson, Arizona, for making available for our use Ektachrome Infrared 1:200,000 aerial photography taken over the Tucson study area. Thanks are also given to him and Douglas K. Warren, also of the U.S.G.S. in Tucson, for their contribution of ground photography for our multiseasonal imagery study.

In addition, Charles T. Mason, Jr., Department of Botany, University of Arizona, Tucson, has been especially helpful in the identification of many herbaceous species in connection with our ground truth and ecosystem classification studies; and Charles D. Bonham, Department of Watershed Management, University of Arizona, has provided some supplemental aerial photography and has consulted with us on numerous problems and ideas relating to this project.

John M. Tromble of the Agricultural Research Service, Tucson, Arizona, gave us valuable assistance and made information available on the Walnut Gulch Watershed where we are concentrating ground truth classification and studies relating to mapping legend development.

PREFACE

During Fiscal '69, we were funded to work primarily on the development of procedures and capability to use space photography in the inventory and analysis of rangeland resources for the complete and integrated land-use planning, development and management of these kinds of resource areas. Our project also included limited support for the analysis of 1966 multi-spectral linescan data obtained by Oregon State University over range resources test sites in Oregon and Nevada. The objective of the latter was to determine the feasibility of automatic recognition of range ecosystems (specific plant community-soil systems) from 1,000 foot multispectral linescan data by use of the Purdue analytical techniques.

When the S065 experiment went aboard Apollo 9 in March, 1969, our Oregon crew joined with Colwell and his group in the necessary ground-truth support of this mission. This necessitated putting the multispectral linescan analysis on the back burner until the last quarter of Fiscal '69. In late July, 1969, a graduate research assistant was employed on the multispectral linescan study and work on this phase was resumed with encouraging preliminary results.

Our plans for the year counted heavily on the Apollo 9 and excellently coordinated aircraft imagery that was concentrated over the Tucson-Willcox-Ft. Huachuca area. We had primary responsibility for range resources ground truth in this area. These plans were partially thwarted by the heavy cloud cover and snow storms that plagued the Apollo 9 program over this area. We did obtain both ground and excellent supporting aircraft data that will be useful in the further analysis of Apollo 9 and S065

photography by selecting restricted portions of the space imagery that are cloud free. We did learn one important lesson in this experiment and that is not to concentrate manpower and immediate prior ground truth studies in such a restricted area as the above triangle. Had we dispersed our manpower and preliminary aircraft reconnaissance over a wider geographic range with plans for quick convergence on the more important study areas as the photo mission count down approached, we could probably have worked more successfully around the ever-present, cloud-cover problem. Colwell and Poulton were able partially to rectify this deficiency, however, by making an immediate post-mission, low-level, aircraft photo-reconnaissance of the Apollo 9 flight path from Dallas, Texas to Phoenix, Arizona. Multispectral, oblique photographs were taken of key earth resources features with hand-held, 35 mm. cameras.

The Oregon group contributed significantly to the Apollo 9 science screening, 30-day, and 90-day reports with particular attention to the S065 experiment.

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INTRODUCTION

Three joint U.S. Department of Agriculture-State Agricultural Experiment Station task forces have identified the inventory of rangeland resources as an important need pursuant to proper land-use planning and to resource development and management in our country. Of these, the Forage, Range and Pasture Research Task Force most precisely defined the problem and need as Research Problem Areas 110A and 110B. The former treats the operational inventory need, and the latter identifies the supporting research on resource ecology that is required to generate the understanding of ground-truth data for the interpretation of imagery and the classification of resource areas into equivalent ecosystems.[1/] In addition, the U.S. Department of Interior

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[1/] The term "ecosystem" has been variously and confusingly used in recent North American literature. We use the term throughout this report to connote a unique and fundamental ecological unit of the landscape. Separate examples of an ecosystem are found at spatially disjunct locations throughout the landscape wherever an analogous or essentially equivalent effective environment occurs. Equivalence of effective environment is indicated by a high degree of plant sociological similarity in the vegetation (the collective group of species) that occupies each separate stand representative of the ecosystem. These individual ecosystems provide the ground-truth base for vegetational or ecological resource legends in the description, mapping analysis, and monitoring of vegetational resources. This concept of the ecosystem is equivalent to the "phytocenose" put forth by Küchler (1967) as the scientific basis for understanding and mapping vegetational resources. It also leads to essentially the same fundamental landscape unit as the "habitat-type" concept of Daubenmire (1968). The ecosystem as defined here is essentially the same plant sociological concept as has been applied by many European workers in the preparation of detailed vegetational resource maps for practical use in planning for the use, development, and management of natural resources (Küchler, 1967).

has recognized the need for analyses and useful maps of the vegetational and related soil and geological resources in rangeland areas through suppor of independent research to develop methods for the ecological analysis of rangeland watersheds (Culver and Poulton, 1968) and by various vegetation and related resource mapping and research projects conducted in areas where range is the predominant resource. Furthermore, both the American Society of Range Management and the American Grassland Council have standing committees that are addressing attention to the specific inventory needs of range and grassland resource areas. Such programs, when they become reality, will have to involve the best of modern remote sensing technology.

Resource monitoring in rangeland environments is an equally important applications area. The resource manager must be sure of the impact of his decisions on the vegetational and soil resource--what are the consequences of man's input to the ecosystems? Remote sensing is the strongest, modern tool available for efficiently answering this question. Remote sensing captures and preserves an accurate record of conditions at an instant in time and makes it literally possible to bring the resource scene into the photo interpretation and image analysis laboratory for detailed study and comparison--thus conserving critical scientific and managerial manpower. Data acquisition is fast and one can thus avoid the seasonal changes that often confound data when resource information must be obtained entirely by slow, ground methods. The speed of data acquisition also makes possible repetitive seasonal coverage--a requirement for certain kinds of resource interpretations needed by rangeland managers. While range managers have been accustomed to complete-area coverage whenever they think of aerial photography, the concept of multiple-scale subsampling by remote sensing

makes repetitive coverage and even color photography economically attractive to the information user. He has tended to consider these latter alternatives economically out of reach, even though desirable, partially because of his tendency to think only of complete-area coverage.

As an aid in the resource stratification initially essential to this multistage sampling technique, the synoptic coverage of space photographs provides a unique opportunity in classification and pre-stratification of both the vegetational resource and the physical environment. Within this kind of stratification framework, efficient subsampling programs can easily be designed to acquire useful resource data at minimum cost.

The research reported here is focused on the development of more adequate and efficient methods to make remote sensing an intimate part of information acquisition for land use and management decisions in rangeland environments. We are striving to capitalize on all appropriate remote sensing capability that is developing out of the Earth Resources Program of the National Aeronautics and Space Administration.

ECOLOGICAL RESOURCE INVENTORY AND ANALYSIS IN THE DECISION AND ACTION PROCESS

When we begin to look at the kind of ecological resource inventory and analysis that has become possible by working from space, small-scale high-flight, and other state-of-the-art aerial photography, we transcend the scope of single-use resource management. We are projected into an area that the range resources staff at Oregon State University has long identified by the simple term "integrated resource management." This encompasses--in its fullest meaning--the concept of multiple-use resource management, the realistic and adequate consideration of all features of the resource,

including human and economic, and a professional dedication to achieve integrated resource management regardless of complex patterns of resource ownership and control. The objective is to bring about maximum, long-term benefit to society through the programs that are effected on the land. Thus, with this new capability, we have an improved opportunity to look at land-use and resource development through the eyes of collective interest, not as mono-discipline specialists. It is no longer just agriculture, forestry, range, soils, geology and minerals, water or aesthetic resources but rather an integrated program to balance civilized man with land, water and air resources on a permanent and lasting basis.

In striving for this objective, we can no longer tolerate the waste of single-use and duplicative resource inventories. The ecological resource analysis comes into its own here and outshines all other more restrictive approaches by its inherently fundamental nature. It provides the permanent working base upon which all specific needs for resources information may be accumulated. The prime requirement is merely that the fundamental mapping units be based on adequate scientific inquiry into the description and classification of the natural ecosystems that provide the reservoir of resources. The wisdom and broad application of vegetation maps derived from sound plant sociological studies and vegetation-environment relationship research is most effectively discussed in a world perspective by Küchler in his book on Vegetation Mapping (1967). He illustrates the many effective uses Europeans and others have made of these kinds of vegetational resource inventories. He appropriately quotes Molinier (1951) who says of this approach that it ". . . is in the front rank of all consideration concerning land use because of the possibilities it makes available to man." Küchler

effectively summarizes what plant community ecologists have known and demonstrated for ages when he says, "Plants are rooted in the soil and exposed to the daily weather conditions of all seasons and can therefore report the nature of the environment much more comprehensively [and with greater biological accuracy] than any instruments ever can." Therefore, " . . . the vegetation reveals at a glance the entire environmental complex, including soil type [where it is ecologically relevant], the physical and chemical characteristics of the soil water, as well as the climatic and biotic features of the habitat." It is to capitalize on these facts that we are striving to apply remote sensing as a tool in looking at the ecological characteristics of the earth's landscapes. One of the main advantages of combining ecology and remote sensing as a team of disciplines is that it conserves scientific and managerial manpower by reducig their field time and travel. It brings a usable image of the field situation to the laboratory and desk of the decision-maker for careful and thorough study. It does not eliminate field work. In the initial developmental stages it may actually require unaccustomed amounts of systematic, field research and observation with imagery in hand; but the end result is certainly to increase the effectiveness and quality of performance of our professional manpower pool in resource management.

Resource Management Functions, A Perspective for Remote Sensing

As we select a remote sensing approach and judge or predict the value and applicability of the interpreted output, it is important to be aware of the three major functions in land use and management, the direction of flow in the decision process, and the relation of remote

sensing requirements to the intensity levels in management. These interrelationships are diagramatically displayed in Figure 1. While this illustration seems to emphasize photo or image scale as the prime remote sensing criterion, both scale and ground resolution are interrelated. Both are important in meeting the respective information needs at each functional and intensity level.

In our judgement, essentially the same requirements would prevail for resource monitoring as for inventory. This illustration should make clear the fact that no one scale and resolution of imagery will serve all needs in the land use and management arena and that space photography of present or contemplated ERTS-A quality will not serve the needs of manage ment except as it may be utilized in multistage sampling. Where, however the decision process is at the policy formulation and broad planning stag space or very small scale aerial photography may be the preferred working imagery. In addition, many land-use questions can be answered or monitored most effectively from this same kind of working material. Very small scale, coarse resolution imagery should be ideal for land-use zoning applications because here the need is to average out or "obscure", in an ecologically meaningful way, some of the intricate detail and pattern in the ecology of landscapes. Thus the derived information is especially compatible with decisions about ecologically appropriate uses and development potentials over rather large expanses of land. Too much detail may actually confuse the decision process; and at the same time, too little detail may result in lack of flexibility in zoning decisions, laws and ordinances. The result would be failure to accommodate the true potential and best uses of uniquely different lands within a zoning area. While very small and intermediate

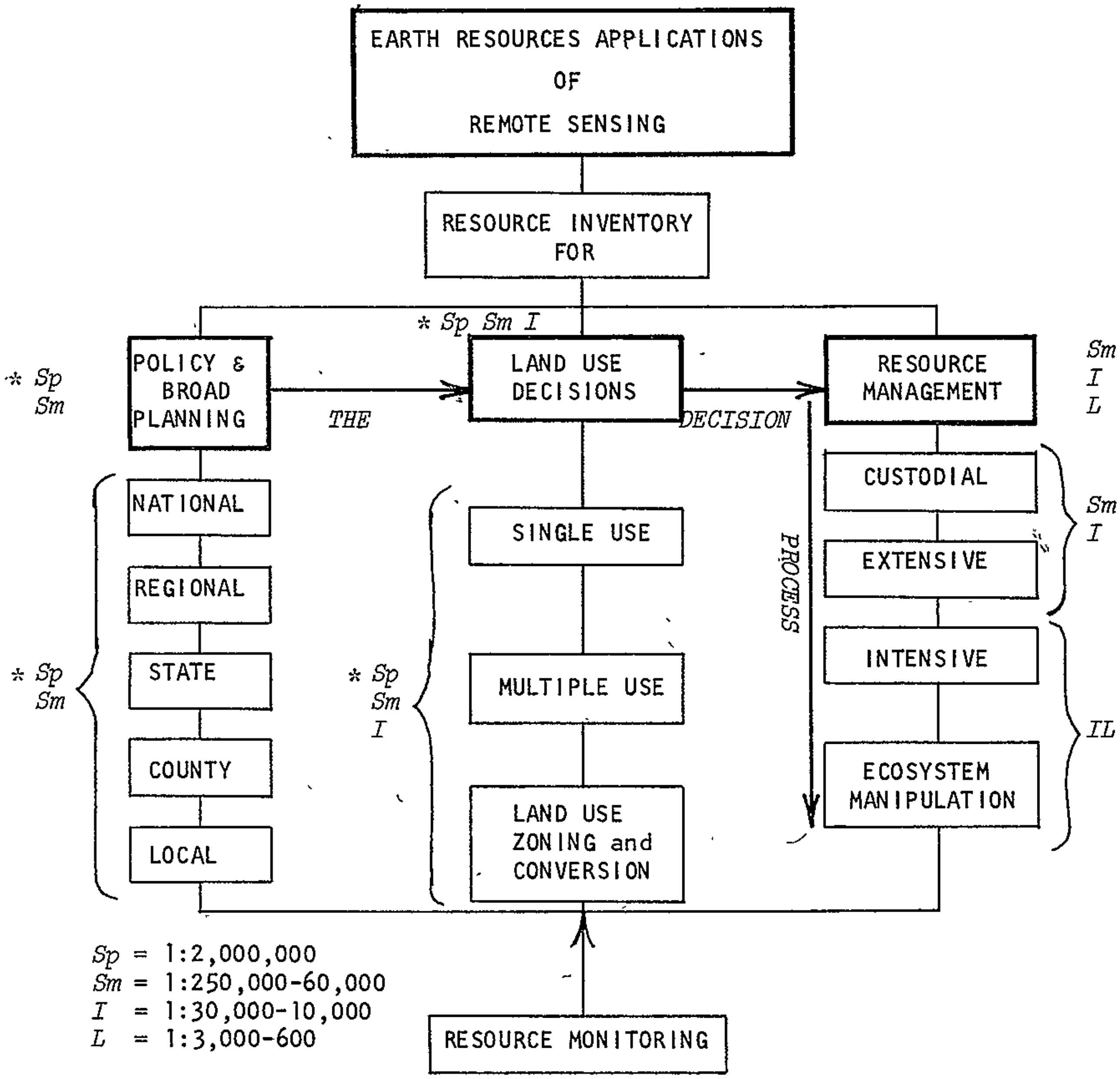

Figure 1. Resource Management Functions in Perspective. This illustration shows the normal flow in the decision-making process in relation to the three major resource management functions and the intensity levels of management. The special suitability of space photography is indicated by the asterisks and abbreviation "Sp". Suitability of various scales, and by implication, resolutions, of aircraft photography is shown by the remaining italicized notations alongside each block. Resource monitoring requirements are essentially the same as for inventory.

scale imagery is usually adequate for custodial and extensive management, state-of-the-art ground resolution and scales of 1:30,000 or larger (preferably in the range of 1:12,000 to 1:15,840) are required for intensive resource management. This is especially true when the manager becomes deeply involved in ecosystem manipulation and what some resource professionals are calling "acre management", that is, where the resource characteristics and potentials on individual acres affect the decision process.

PROCEDURES

A Résumé of Procedures Continued or Modified

During the 1969 Fiscal Year, we have followed the ecological and cartographic concepts, principles, and procedures as outlined in our 1968 Annual Progress Report (Poulton, et al., 1968). We have had no cause to modify these guidelines. They were developed and tested in the conduct of operational resource analyses from conventional black-and-white aerial photography in Oregon [1/] and all have been found appropriate to space and multistage, aircraft-photography applications.

Our ground-truth field procedures have remained the same as outlined in the above report with the exception of a few refinements and additions. The vegetational and soil surface characteristics were recorded as indicated. Records were taken of the species composition, prominence, and cover at

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1/ Essentially these same procedures were used in the survey and ecological resource analysis of over 600,000 acres of rangeland for the Oregon State Land Board. Eighteen percent of the parcels were ground checked and the remainder were photo interpreted. Checks on photo interpretation indicate an average accuracy of 69 percent. Individual interpretations ranged from little better than a guess where great reliance had to be placed on associated and convergence of evidence and the interpreters had minimal experience to nearly 90 percent. A limited number of features were interpreted with over 90 percent accuracy.

sample locations representative of each plant community found in the study area. At each observational site, those soil surface features likely to affect photo image characteristics were also recorded--surface color, gravel and stone cover, exposed mineral soil percentage, and litter cover. Physiographic features likely to be useful as associated evidence in photo interpretation and image-ground truth relationship studies were also recorded--elevation, macrorelief, landform, slope and aspect or direction of slope. All observational sites were located precisely on each stage of aerial photography and as closely as possible with reference to the image represented on the space photogtaphy. In most instances, a ground photograph of the vegetation and soil conditions was taken and cataloged as additional documentation and a potential aid in training photo interpreters.

These data are currently being analyzed and classified on a plant sociological basis into individual ecosystems and similar ecosystem sets. These constitute the ground-truth units that will be:

1. Compared with image classes to develop interpretation keys and aids;
2. Used as the basis for an operational, mapping or symbolic legend; and
3. The primary data record from which descriptive legends of each resource class and identifyable image can be written in preparation for an operational test of multistage sampling.

We have up-dated our Work Flow Chart presented in the 1968 Annual Progress Report with some minor modifications and embellishments, but the procedure for development of an operational system to use space imagery remains the same as envisaged and diagrammed in Figure 1 of that report.

Because of cloud problems in connection with the Apollo 9 mission and the S065 experiment, we restricted our area of concentrated field work during

1969 to the essentially cloud-free Tombstone-Ft. Huachuca vicinity. Here we were also able to make comparisons with vegetation classification and mapping done by the Agricultural Research Service on the Walnut Gulch Watershed near Tombstone (USDA, ARS, Soil and Water Conserv. Res. Div., 1967).

Procedural Modifications and Adaptations

Using our ground information methods, we took a large amount of data in support of the Apollo 9 and subsequent high-flight missions. This also included both oblique aerial photography and mapping from low-flying aircraft. We requested NASA aircraft support photography in 1968 but copies did not become available until after the Apollo 9 mission so we had to adapt to the use of 1:250,000 topographic sheets for some of our ground-truth control and initial mapping of details. The U. S. Geological Survey had previously made available to us some approximate 1:200,000 color IR photography and Robert C. Heller of the U. S. Forest Service had taken some 70-mm. photography for our project; but unfortunately, it was largely in areas covered by clouds in the Apollo 9 experiments. Because of this necessity to rely on topographic maps, we transposed the ground location of all resource data records to the Universal Transverse Mercator Grid system; and this promises to pay dividends in subsequent data management. In addition, all photography from low-flying aircraft has been rather accurately located on the 1:250,000 topographic sheets. This greatly facilitates usefulness of the photo record.

In connection with the concurrent Apollo 9 ground truth acquisition, we adapted and tested a rapid method for annotating these records by use of our first iteration of the vegetation legend and certain other modifiers

representing ground features that most strongly influence the photographic image. This technique can be used with high effectiveness from a small airplane or helicopter and can also be used to quickly record or summarize ground-acquired records. The components of this annotation system are shown in Appendix A and B-3.

Once the legend and ground vegetational characteristics are learned, this observational method proved highly efficient from a relatively slow-flying aircraft. It works ideally with three observers--one ground observer who calls off the legend components; a recorder and ground-contact navigator who also marks the route of flight, checks and/or maps ecosystem boundaries on a topographic sheet or aerial photograph, and writes down the symbols as called out by the first man; and a photographer who takes low oblique and near vertical photographs with a hand-held camera to document the various ecosystems. He calls "mark left!" or "mark right!" with each photograph and the recorder marks and numbers sequentially a (v) pointing outward from the appropriate side of the line-of-flight trace. In this way, the supporting photos are automatically located and annotated. When developed and/or printed one merely needs to sequentially number all support photographs from the mission and add the date and flight path designator to the photo file, negatives, transparencies or prints. An example of application of this legend is shown in Appendix A.

When the NASA photography from 1968 became available to us, it was most helpful in improving our ground truth acquisition and the characterization of images in terms of the ecosystems or ecosystem sets they represent. Our area of concentrated study was pre-stratified on space photography, and on the sample strips of 1:200,000 and 1:20,000 photography. This stratification

into unique photo images was used as the basis for selecting representative sets of ground truth stations and to avoid overlooking important ecosystems. A study of the variability of image within mapped areas was the basis for deciding on numbers of sample locations. Each of the mapped delineations was characterized according to the mapping legend (Appendix B-3) and these photo interpretation decisions were field checked in connection with travel to ground-truth stations.

We gathered range resources ground truth in connection with the 1969 high-flight program in collaboration with personnel of the Forestry Remote Sensing Laboratory. Fifteen carefully chosen ground-truth stations were photographed from the ground and plant development (phenology) records were taken in connection with each overflight through the growing season and into the dormant period. These records are particularly designed to aid the study of the multiseasonal signatures of range ecosystems and prominent species as recorded on photographic film.

In late July 1969, we were able to return to the analysis of our 1966 multispectral linescan data as a contribution to a signature bank of rangeland ecosystems and to assess more thoroughly the capability of this system to automate the identification of important and useful rangeland features. This work is utilizing Purdue LARSYSAA programs and the work is being coordinated and conducted through Jerry Lent's program at the Forestry Remote Sensing Laboratory, Berkeley.

MAPPING LEGENDS FOR ECOLOGICAL RESOURCE ANALYSIS

The natural resource manager has need for almost unimaginable volumes of information as background for his decisions and action programs. His

information about the physical resource is nearly all ecologically based, and since the range, forest, watershed and often the recreation manager is concerned primarily about vegetational and soil resources, his initial interest is toward the plant ecology and vegetation-environment relationships evident on the landscapes. To this he adds facts and understanding relating to the broader human ecosystem--the psychological, sociological, economic, and political environments of man--in reaching his decisions.

In order to synthesize this complex package of information to a useful point, the manager must be provided with classifications and a way of reducing the data to a point of comprehensibility. This is one of the functions of the ecological legend in resource analysis. The complete package consists of a symbolic legend and a descriptive legend. The former is a kind of shorthand that accomplishes much of the above objective of classification, information, and reduction. In addition, the symbolic legend makes it possible to record tremendous amounts of information in small spaces on maps and in tabular summaries. The descriptive legend, on the other hand, allows the user to rebuild, in its complete form, the detailed information about each symbolized unit.

A Vegetation-Environment Symbolic Legend

Our work during 1969 concentrated heavily on the classification work required to adapt long-established legend concepts to the analytical and mapping requirements of multistage, earth-resources imagery. Special attention has been given to the ecology of natural landscapes and to the integrated treatment of land use where man has sharply modified the natural environment and altered uses of the land and continental water resources.

Ours is a non-connotative, closed legend system that has a logic particularly adapted to remote sensing and multistage analysis of earth resources. It is a system that progresses from the general to the specific as one moves from left to right through the symbol in a numerator/denominator format. The numerator treats vegetational features and the denominator treats features of the earth environment. The first entries on the left define those features most easily discerned from space photography and the most right-hand entries define features interpretable only from very large scale photography or from ground examination (Figure 2).

This report includes both an abbreviated form of the first iteration of the vegetational legend (Appendix B-3) and the subsequent generalization of selected components of the legend to permit application over a wider area than the immediate study site in southern Arizona. In each case we have tried to set up classes that are consistent with what one can reasonably interpret from appropriate imagery--recognizing that remote sensing may never be able to replace the need to obtain some items of information from ground examination.

<u>Primary Vegetational and Land-Use Class</u>:

This class is represented by the digits to the left of the decimal point in the numerator (Figure 2). The class treats vegetational, land surface, and land-use features that can most easily be discriminated from space and small scale photography. Eleven classes are included in the set consisting of seven native vegetational categories, a barren lands, a water resources, and two land-use classes (Appendix B-1). All these have been encountered in the southern Arizona test area except Class 70.,

Figure 2: An Ecosystem Legend Format for Range Resource and Land Use Analysis from Space and Supporting Aircraft Imagery.

Generalized Form:

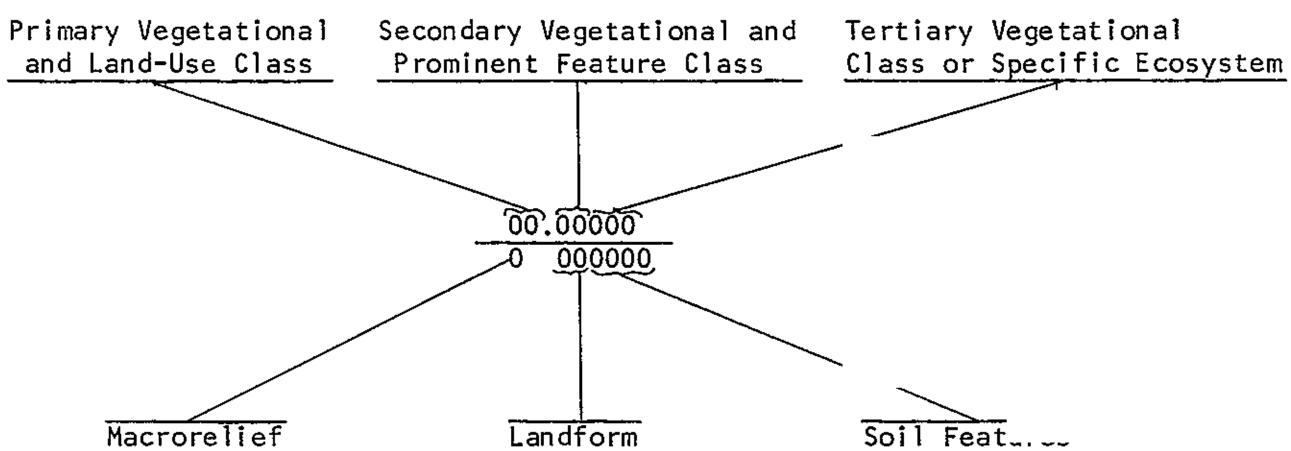
Vegetational Features

general ———————————————— *specific*

Environmental Features

Specific Form:

Resource Classes Based on Vegetational Indicators



Alpine-Tundra/Arctic-Tundra, and Class 80., Vegetation of Aquatic Environments. An attempt was made to design these classes for world-wide applicability. A subordinant breakdown of Class 10., Barren Land; 90., Water Resources; 100., Agricultural Land; and 200., Urban and Industrial Land, is shown in Appendices B-2, B-4, B-5, and B-6, respectively.

<u>Secondary Vegetational or Prominent Feature Class</u>:

This class is represented by the first two digits to the right of the decimal point in the numerator (Figure 2). The classes at this level are currently being defined. They are based on prominent floristic or landscape features that are common to sets of similar ecosystems. Here, again, a diligent effort is being made to develop classes that are relevant to remote sensing image interpretation capability and at the same time ecologically meaningful. While the primary classes seem to fit world-wide conditions, it appears that some of the secondary classes may have to be developed separately by broad ecological regions or provinces.

The first iteration of our legend (Appendix B-3), while in a different decimal form, is indicative of one approach to these kinds of broad groupings. These are reasonably appropriate to the Tucson-Willcox-Ft. Huachuca test area. The two digits shown in this appendix could be used to form the secondary vegetational class but we are not well satisfied with these categories and are striving to make improvements. In the course of these attempts at improvement, we have examined the work of many well-recognized plant geographers (Küchler, 1967); but all have some shortcomings in relation to photo interpretation of vegetational classes. It appears that our eventual legend will be a synthesis of many efforts plus our own judgment

about compatability of the legend with image analysis and interpretation objectives. Part of the second iteration of this section of our legend is shown in Table 1. This legend has not been extensively tested, it is tentative and is presented only to illustrate the format of the contemplated second generation of the vegetational legend. It is hoped that other potential users may react to the legend concept and, thus, help us to improve on the symbolic legend system and/or the approach to classes used at this level. A similar pattern is being worked out for the identification and notation of agricultural crops. It appears to work rather well.

Table 1: A second-iteration example of the vegetational legend generalized to fit more widely in the southwestern United States.

Symbol	Class Description
50.	Savannas
51.	Evergreen, Tall-Shrub/Tree Savannas
51.10	Hardwood/Needleleaf Savanna
51.11	Evergreen Hardwood Grassland Savanna
51.11000	Specific Plant Community Descriptors
51.12	Needleleaf Grassland Savanna
51.13	Evergreen Shrub Grassland Savanna
52.	Deciduous Tall-Shrub/Tree Savannas
52.10	Tall, Deciduous Shrub Grassland Savanna
52.20	Deciduous Tree Grassland Savanna

<u>Tertiary or Specific Ecosystem Class:</u>

The specific ecosystems comprising the naturally vegetated landscapes of the test area have not been worked out and published in the literature. Many maps have been prepared and their respective legends are generally constituted for utilitarian purposes or are an amalgamation of ecosystems above the fundamental or taxonomic unit level. They are, thus, valueless for photo interpretation at ecosystem level because they do not identify the individual plant communities and soil conditions that are responsible for the unique images registered by remote sensing. The efforts of one Graduate Research Assistant, Edmundo Garcia-Moya, are being directed toward this problem and the study of photo image-subject relationships.

In order to provide an idea of what the eventual legend will look like at this finest level, Table 2 shows a specific ecosystem legend developed and used for mapping in the "Salt Desert Shrub" zone of Oregon (Martin 1969). The species symbols identify the prominent or character species for each plant community, or specific ecosystem. The parenthetical numbers following each species symbol shows the range of prominence scores, or relative importance, of the character species. Since these communities are the mirror of their environment, these 3-digit symbols provide a world of information about the vegetation, soil and other features of the environment.

Macrorelief Classes:

In the geomorphological and soils literature, there is much confusion among some of the gross and subordinant classes that have been used to characterize the earth surface. By approaching the question from the viewpoint, "What is ecologically relevant?", we have been able to put

Table 2: An example of a specific plant community, or ecosystem legend widely used for resource analysis in Oregon. These legend symbols are used in the extreme right-hand end of the vegetational resource legend; thus, __.__000.

Symbol	Plant Community
110	Atriplex confertifolia communities
111	Atco (4-5)-Arsp (3-4)/Sihy (3-5)-Brte (0-3)
112	Atco (4-5)-Arsp (3-5)-Grsp (2-3)/Sihy (1-5)-Brte (0-5)
113	Atco (4-5)-Arsp (3-4)-Save2, Chve, Chna (2-3)/Sihy (3-5)-Pose (2-3)-Brte (0-5)
114	Atco (4-5)-Arsp (3-4)-Grsp (1-3)/Meal2 (3-5)-Sihy, Brte (0-3)
140	Eurotia lanata communities
141	Eula (5)/Pose (0-3)
150	Sarcobatus vermiculatus communities
151	Save2 (4-5)-Chvi (3-5)/Dist (5)-Elci (0-4)
152	Save2, Artr (3-5)-Grsp, Chvi (0-5)/Sihy (1-5)-Elci, Brte, Meal2 (0-5)

together a macrorelief classification that is more meaningful and useful to the ecologist and resource manager than has been the direct use of terms and classes from the available literature.

It seems logical to set up macrorelief classes that describe natural land surface conditions ranging from flat and smooth to extremely steep and rugged and from simple drainage patterns to complex patterns. These classes can be assigned to land surface characteristics without primary regard for geological origin or process. The latter is more directly related to landform, a subordinant category within macrorelief as we view the problem. Our macrorelief classes describe those broad land areas that are tied together by similarities in (1) the amount of elevational difference or relief, (2) the nature and complexity of slopes and abruptness of slope changes, and (3) the complexity of drainage patterns. Macrorelief is thus the largest category, the highest hierarchal level in the classification of landscapes. It refers to the largest scale inequalities in the landscape and is, in fact, best discerned on photo scales of 1:63,360 and smaller. Space photography of the quality of Apollo 6 with stereoscopic viewing is ideal for the analysis and mapping of macrorelief.

We have developed and widely used the following macrorelief classes in many different environments:

1. Flat Lands
2. Undulating and Rolling Lands
3. Hilly Lands
4. Mountainous Lands

These classes are fully characterized in Appendix C-1. Since macrorelief classification is important in both characterizing the environment and

narrowing down legend choices in the interpretation of vegetation, we conducted a simple experiment with two observers to determine the consistency with which they scored macrorelief from stereoscopic viewing of Apollo 6 photography and to identify some of the problems in macrorelief mapping. In this test, each man worked only from the same set of written instructions and intentionally did not train together or compare delineation decisions or identifications prior to the test. On high resolution color and color infrared photography of appropriate scale, many image features are directly related to vegetational characteristics; but as scale and resolution decrease, vegetational interpretations must rely more and more on associated and convergence of evidence. This requires a rich ecological experience and fund of knowledge about vegetation-environment relationships to identify the criteria from associated and convergent evidence which improve the subject-identification decision. Macrorelief and attendant landforms are two of the most useful kinds of associated evidence in vegetation interpretations. Prestratification into these alternative classes reduces choices in the decision process and tends to increase the accuracy of identification, particularly among less experienced vegetation interpreters (Table 3). Delineation and identification results were compared by determining the areas from Frame AS-6-1442 placed in the same class by each of the two interpreters. The results were considered highly successful in terms of macrorelief class recognition but highly unsatisfactory in the way in which the two men grouped classes when delineating complexes (mixtures of two classes) rather than pure classes.

Landform Classes:

Table 3: Macrorelief and landform provide convergent evidence in vegetational interpretation from space and high-flight photography.

Macrorelief Class	Most Likely Vegetation or Ground Feature (Legend Symbol)
Flatlands	
Bajadas, Fans or Terraces	01.1, 01.2, 01.3, 2.1, 2.2
Bottomlands	02.3, 03.7, 03.81, 03.82, 09.1, 10.0, 12.0
Hilly Lands	01.4, 04.0, 05.0
Mountains	04.0, 05.0, 06.0

The development of landform classes that are meaningful to the ecologist and vegetation resource manager seems to present a real dilemma. The primary need of these people is for landform classes that are relevant to vegetation development and productivity as well as being significant in resource management decisions. Except for mechanical problems of access and utilization of the resource area, landform features that are relevant to vegetation or to vegetation-soil systems are also the ones relevant to management. Many landform features important to the geomorphologist produce the same effect vegetationally. Thus, if we attempt to use directly the many class names from this literature, we are plagued by synonomy in ecological impact among "separate" landforms. Thus, it appears again that the ecologist and resource manager must improvise his own system for treating the relevant physical features of the earth surface.

A suitable system for classifying the ecologically relevant features of the earth's surface should, in addition to macrorelief, reflect the following ecologically important differences in the land surface:

1. Uplands versus lowlands.
2. Exposed versus protected slopes.
3. Steepness of slope, length of slope, and position on slope where these features are relevant to vegetation change.
4. Those landform classes that result from strongly contrasting or unique geological influences that are particularly relevant to soil formation, vegetation growth and development, and thus to the ecosystems found on the land.

Considering these points, the Oregon team has put together a classification of Relevant Physical Features that has worked reasonably well. This has been through many revisions and has been tested from the southern coastal

plain to the southwest and northwest with reasonable success. The classification is presented in Appendix C-2. Only a few of these 10 primary and 16 secondary classes can be used in the interpretation of space photography; but in the setting of multistage ecological analysis of earth resources, they play a strong role. Again, as with the macrorelief classification, they tell the user things of value about the landscape and also aid the photo-interpreter or image analyst by providing associated and convergent evidence in the image identification process.

Legend Application in a Subsampling Mode

In connection with our intensive field work during 1969 in the Tombstone vicinity, we mapped all available photography, space and aircraft, with the use of the first iteration of our vegetation mapping legend (Appendix B-3). We were not able to do random subsampling from supporting aerial photography as would be required in an operational survey. We did, however, illustrate and partially test the procedures. They were simulated by using selected frames from the various scales of photography flown by NASA and USGS along sample flight-lines we had designated in the Tombstone-Ft. Huachuca area. The procedure calls for progressive mapping, interpretation and image identification at legend recognition levels appropriate to each scale and resolution of photography. The space photography provides the initial stratification of the landscape into broad macrorelief, primary vegetational and land-use classes according to the legend (Appendices B-1, C-1). Such broad-scale mapping is illustrated in Figure 3A showing the Benson-Tombstone-Ft. Huachuca, and San Pedro River area on a portion of Apollo frame AS-6-1442. This is a gross but highly informative "cut" at macrorelief,

Figure 3. The facing set of photographs illustrates the application of our mapping legend concept and of multistage subsampling in the inventory and ecological analysis of arid-region, vegetational resources. The set shows how space photo images may be explained and characterized by subsampling and how increased amounts of information may be derived from the concomitant analysis of supporting aerial photography at progressively improved scales and ground resolution (Tables 4 and 5).

Figure 3-A represents a portion of Apollo frame AS-6-1442 over the Benson-Tombstone-Ft. Huachuca area of southeastern Arizona. The mapping units in this figure were determined primarily by macrorelief features and secondarily by the primary vegetational classes and complexes (mixtures of classes) that are found on each kind of macrorelief. The arrow indicates a delineation chosen for a subsampling study.

Figure 3-B illustrates more intensive mapping on a portion of AS-6-1442 that was subsampled by 1:200,000 photography (solid quadrangle) and by 1:20,000 photography (smaller dashed quadrangle). This more intensive mapping from space photography was based equally on major vegetational classes and on macrorelief. Photo scale is 1:715,000.

Figure 3-C is a 1:1 reproduction of part of the 1:200,000 frame covering the solid quadrangle in 3-B. Interpretation at this scale is based primarily on vegetational classes and secondarily on macrorelief and landform features. Note the increase in the mapped detail that is possible. Most of the mapping units are composed of one vegetational class. The improvement of both scale and ground resolution is responsible for the increased precision of mapping at this stage. The solid quadrangle in 3-C compares to the dashed quadrangle in 3-B and in the area covered by one frame at 1:20,000.

Figures 3-D and E are 1:1 reproductions of part of the 1:20,000-scale subsample. Their locations are indicated in 3-C by the letters "d" and "e", respectively. Note that this scale and resolution permits interpretation and mapping of individual taxonomic units (specific ecosystems) based on vegetational and soil surface detail as registered on film.

3-A

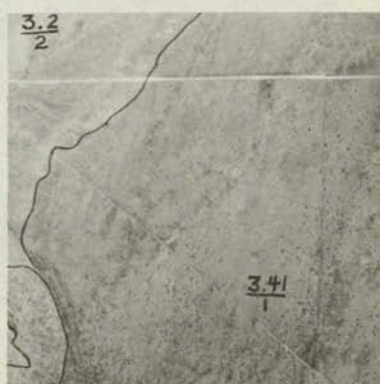
3-B


2.6
2.4
2.5
2.2/3.83
2.5
2.6
2.4
3.8
3.2
2.2
3.4

3-C


2.4
3
2.2
1
3.2
1
2.4
3
3.81
1
3.6
1

3-D


3.2
2
3.41
1

3-E

vegetational, and land-use mapping for this area. The frame obviously could have been mapped more finely into smaller, essentially "pure" delineations; but, in this instance, the gross features of macrorelief were allowed to control the mapping intensity. Subdivisions were made into large, meaningful areas of pure and complex vegetational and land-use delineations designated at primary and secondary legend level. A treatment such as this can form the basis for aerial subsampling to more precisely define the vegetational and land-use components of the delineations and to develop statistics relevant to these landscape features.

Concentrating on the large, predominantly blue delineation in the Tombstone vicinity (see arrow, Figure 3-A), we will illustrate the subsampling approach. From this initial stratification and interpretation, this area is judged as predominantly rolling to undulating. This macrorelief class generally supports plant communities in which _Rhus microphylla_, _Acacia constricta_, _Nolina microcarpa_, _Yucca baccata_ and _Larrea tridentata_ predominate. Of second importance within the delineation is a mixed rolling and hill-lands complex where _Mortonia scabrella_ - _Acacia constricta_ vegetation is known to dominate extensive areas underlain by a caliche pan (USDA, ARS, Soil and Water Cons. Res. Div., 1967). Flat lands are third order importance in the area. They are suggested by certain of the narrow, dark-blue streaks in the undulating to rolling macrorelief area. These are actually narrow bottomlands dominated by dense stands of tobosa grass (_Hilaria mutica_).

Even this crude map provides substantially more information than is available from any of the published small-scale vegetation maps of the area (Humphrey, 1963; Küchler, 1965; Carneggie et al., 1967. In

addition, the mapped boundaries are both more meaningful and probably more accurate because they are photographically determined. Obviously, this level of interpretation is possible only after one has developed a substantial understanding of the phytosociology and vegetation-environment relationships in the area by ground-truth studies.

We will now consider how this picture can be refined by subsampling with supporting aerial photography. More refined mapping can be done from the space photography as is illustrated in Figure 3-B. Approaching the mountains in the upper right-hand corner of the photograph, there is an extensive grassland area not separately annotated in Figure 3-A. It is characterized by the following species: Bouteloua eriopoda, Bouteloua curtipendula, Hilaria belangeri, Aristida species, and scattered shrubs such as Yucca elata, Yucca baccata, Prosopis juliflora, and Ephedra trifurca. This vegetation area is evident and mapable in the space photo (see $\frac{3.0}{2}$ delineation, Figure 3-B). This figure is a copy of part of AS-6-1442. The outlined area was also covered by one frame of USGS photography taken with their KA50A camera and 1.75" lens at an original photo scale of approximately 1:200,000. In an operational subsampling survey, these would obviously be precisely located with respect to selected random sampling points or transect lines. Since we were not able to plan an ideal subsampling approach, we used what was available for illustrative purposes under the condition that additional larger-scale photography had to also be available for part of the area covered by the USGS frame (note small dotted square in lower center of the mapped area of Figure 3-B).

By more refined mapping and interpretation of the space photography, one can make a second iteration of the vegetational and land-use analysis.

In this instance, the sample area defined by one frame of 1:200,000-scale aerial photography was characterized from the space photography and the results are summarized in Table 4, Column 2.

If more detail or higher accuracy is required, the first step in subsampling follows. These crude statistics can be checked, verified, or corrected from analysis of the 1:200,000-scale photography (Figure 3-C) and the statistics for the selected sample area improved. For example, interpretation of Figure 3-C shows considerable refinement of the resource statistics (Table 4, Column 3); and because of the higher resolution, the identification decisions are more accurate. The larger scale also enhances the information obtainable from interpretation and mapping. For instance, the highly productive tobosa grass (Hilaria mutica) bottomland was barely discernable on the space photograph as a thin, dark-blue streak, but it shows in Figure 3-C as a well-defined type (note the dark-toned strip designated 3.8). Notice, further, that on this 1:200,000 photo, the light yellow areas within the type suggest that the tobosa grass bottom is not pure but that there are numerous small inclusions of differing character scattered throughout. A resource area that from space photography appeared to be a pure bottomland type now appears as a complex of two different subjects. They can be seen with sufficient clarity in the second stage to suspect that they are two different kinds of grassland, but it remains for the third stage to discern the true identity of these areas.

As more detail or higher accuracy becomes necessary, the second level of subsampling at scales of about 1:20,000 to 1:12,000 comes into use. At these scales and with adequate sampling intensity, one can obtain the facts required for detailed planning, land-use zoning, and even some levels

Table 4. A Summary of Resource Statistics for Identical Areas from the First and Second Stage Analyses by Space and Supporting Aircraft Photography.

Resource Feature or Class	PERCENT OF AREA From Space Photography 1:715,000	PERCENT OF AREA From Aerial Photography 1:200,000
2.2	38.9	37.5
2.2/3.43		5.0
2.2/3.83		5.3
2.4	6.0	7.3
2.5		6.9
2.6	5.1	9.0
2.7		4.3
2.8		1.7
3.0	17.1	
3.2		8.4
3.22		3.0
3.4	25.5	7.0
3.41		1.3
3.8		0.3
5.0	7.4	2.9
11.1		0.4
100%	100%	100.3%

of custodial and extensive management without complete-area mapping.

This level of subsampling is indicated by the small dashed square in Figure 3-B and the small solid-line square in Figure 3-C. Each of these areas outlines the land covered by the NASA 1:20,000-scale photograph, part of which is reproduced in 1:1 copy in Figures 3-D and 3-E. This copy has retained most of the detail recorded in the original RC-8 high resolution transparency. From stereo examination of the original 9 x 9 transparency, a trained interpreter can identify practically every resource feature in the subsample. The effectiveness of this and all previous stages of interpretation is dependent on the adequacy of ground-truth classification into the ecosystems or ecosystem sets responsible for the characteristic images in the photography used at each stage. Thus, the resource analyst is able to work backwards through the stages to the space photograph--assuming that all important space photo images have been subsampled--and define the characteristics of the areas imaged from space with a high degree of statistical and ecological accuracy.

Again, in this instance, a comparison among the three stages is appropriate. Table 5 summarizes the characteristics of the minimum subsample area (1:20,000) from the space photo, from the 1:200,000 USGS high-flight photo, and from the 1:20,000 NASA photo.

At either of these three stages, the percentages can easily be converted to approximate acreages; and either level of intensity may meet the informational needs for broad regional planning and land-use policy formulation. Accuracy levels for detailed planning generally will require the refinement of the third stage; and for some applications, acreage determination may require correction to a planimetric base. For some special

Table 5. A Summary of Resource Statistics from Three Stages of Analyses with Space and Two Levels of Supporting Aircraft Photography for the Area Represented by the Largest-scale Sub-Sample (1:20,000).

Resource Feature or Class	PERCENT OF AREA		
	Space Photography	Aerial Photography	
	1:715,000	1:200,000	1:20,000
2.2	40.0	14.5	21.0
2.2/3.83		13.2	
2.4	5.0	6.6	6.0
3.0	25.0		
3.2		15.8	17.1
3.4	30.0	39.4	
3.41			38.7
3.5			3.2
3.6			3.4
3.8		10.5	
3.81			10.6
100%	100%	100%	100%

purposes, such as determining condition or productivity of the resource, a fourth, larger-scale stage may be required, 1:3,000 to 1:600.

Thus, by the combination of multistage subsampling and progressive interpretation on a proportionate or probability sampling design yet to be defined and tested, it may prove feasible to make comprehensive vegetational resource and land-use surveys by the use of synoptic space photography for the first stratification level and as a base for the statistical summary in county, state, and regional applications. For many purposes in broad policy and regional planning, the detail represented in mapping and characterization of earth resources from space imagery may be particularly appropriate to these applications.

Once procedures are developed for explaining the nature of space photo images by aerial subsampling and obtaining the refinement of resource statistics on kinds, areas, and conditions of vegetational and land-use features, it would appear that we may be ready to go operational with a practical system for earth resource analysis. A system similar to that conceived here should make comprehensive recurrent inventories and monitoring of the vegetational and soil resource features of man's environment as well as his uses of the land both feasible and practical. This should be a tremendous aid and time-saver for all counties and states concerned with land-use legislation, policy, zoning, planning, and some phases of management.

Many problems remain to be solved in developing an optimum, operational system. Once multiseasonal, space photography or imagery in multispectral or reconstituted color infrared mode becomes available, the accuracy and benefits from initial stratification should be immeasurably increased over

what we have been able to achieve with the Apollo 6 photography in this report period. The logistics of subsampling need to be developed for efficiently obtaining the supporting aircraft photography. The number of levels of subsampling and the optimum scale for each level are unsolved problems. These could be assumed to vary with the type of vegetation and resource area. To date, we have merely used what was available but results are encouraging where the plant societies comprising the vegetation are sufficiently well known. Sampling intensities at each stage will obviously affect total cost of the resource analysis and these possible combinations need to be optimized. The relative cost and other advantages of a 70 mm, 5-inch, and 9-inch film format for aerial photography needs to be considered in relation to area observed per subsample and the interpreter efficiency when working with the various film sizes. The possible usefulness of panoramic cameras for the first stage might be considered but the advantages of vertical photography would initially seem to outweigh the wider swath width obtainable with the panoramic camera. Different film and filter types could also be considered but it now appears that color infrared and color film are preferred in that order for most vegetational subjects and many soils differentiations.

MULTISEASONAL IMAGERY

Work to date on photo interpretation of the various photo missions and film and filter types indicates that no one season of photography is ideal--or even adequate--for the delineation and identification of vegetation from space and small-scale high-flight photography. One of the inherent features of vegetation is its seasonal change throughout the year. Site induced influences bring about variations in the species composition among different plant communities or vegetational types. This, together with the fact that these species have different phenologies (seasonal growth and development patterns) suggests that we have a powerful tool for remote sensing of vegetational resources in the concept of multiseasonal imagery in the appropriate band or bands.

Rationale

Ektachrome infrared photography obtained as a part of the S065 experiment showed that photographic images obtained from space could differentiate variations of infrared reflection from surface features on earth. These images were characterized by varying intensities of red color which probably related to several variables--most important of which were the structure of the vegetation type, phenological patterns of the plants involved, and the infrared reflectivity characteristic of different plant species.

Because Ektachrome Infrared film effectively protrayed some natural vegetations on the basis of their near infrared reflections, the question was posed: "Can Ektachrome Infrared film be used as an effective tool for identifying kinds, amounts and locations of native vegetations solely on the basis of their relative reflectivities in the near infrared region of

the electro-magnetic spectrum?"[1/] Work already conducted suggested that the answer might be "yes".

Carneggie (1968) reported a superiority found with Ektachrome Infrared Aero film over panchromatic and color films for delineating vegetation and soil boundaries and classifying vegetations into broad types; and this capability was optimized by choosing proper time of photography, i.e., predominant species nearing maximum foliage development and by selecting a scale of photography appropriate for recording the desired information. This latter point related to plant size and densities. Carneggie stated that detection of range plants with sparse distributions required high resolution and/or large scale photography. The presence of plants with high distribution density was detected on smaller scale, lower resolution photography. This was demonstrated by the images on space photographs obtained on the Apollo 9 flight. The annual grass Bromus rubens contributed a high density understory cover to desert shrub communities and also was responsible for high infrared reflection recorded on the film. A similar description is applicable to the vegetations and photographic images of the hills and mountains. The chapparral, oak woodlands, and conifer forests are dense vegetation types. In both cases, the infrared reflectivity of the plants and their cover values were of sufficiently high magnitude that their presence was recorded on very small scale photography having a ground resolution of approximately one hundred feet (see Colwell, 1969, Figures 3.26 and 5.7).

1/ For the purposes of this work, the near infrared portion of the electromagnetic spectrum is considered as .70-.90 microns--the portion of near infrared radiation to which Ektachrome Infrared film is sensitive.

The Problem and Approach

The problem of developing an answer to the question lies not only in determining the most appropriate method for using the film and analyzing the data obtained on the film, but also is dependent on gaining an understanding of the subjects being photographed, i.e., stands representing vegetation types. A dependable, functional system must accurately identify all the vegetal components of a landscape at a meaningful level of classification. This is in lieu of merely identifying the most easily recognized, although this is a logical starting point. Answers to the following additional questions are needed: What are the vegetation types present in a region? What plant species are predominant in each type? What is the phenology and variation in near infrared reflectivity of each species through the year? What are the typical cover values and distribution patterns for predominant individual species of each type and the total cover value for all species in the type?

First the vegetation types in a region must be identified and grouped into one of the following three categories: evergreen, cool season deciduous, and warm season deciduous. The evergreen types are predominated by plants which retain green leaves or needles the year round. The fleshy stems of the cacti retain their green color year long and, therefore, they also belong to this group. The predominant plants of the cool season deciduous types reach their maximum foliage development in the spring of the year, and those of the warm season deciduous types after the summer rains. The time of greatest infrared reflection from the latter two categories coincides with the time of maximum foliage development. Therefore, aerial Ektachrome Infrared photography would best detect the three categories in

early or late winter, spring, and late summer, respectively. This assumes that the predominant plants will have a sufficiently high cover value and infrared reflectivity to contribute the major proportion of infrared reflection recorded in the photographic image. This is not expected to be true for all vegetation types. Thus, it may be necessary to study the subordinate species, was well as the predominant, to determine their contribution to the total vegetal cover of a type and also to the infrared record obtained on film. These data (re: the structure of vegetation types) are being gathered in the manner described by Poulton, et al., 1968.

During the past year, a series of ground Ektachrome Infrared photographs were taken in conjunction with the high-flight program conducted by NASA. Fifteen photographic stations were chosen on April 23 and rephotographed on May 21, 22; July 1; August 30; September 30; and October 30. Each of the photographs was studied and the identifiable plants were visually ranked as having either No, Low, Medium, or High infrared reflectivity. This ranking was accomplished by judging the amount of red color recorded in the photographic image. The reliability of these visual rankings was tested by measuring the optical density of these same images on a fifteen percent sample randomly chosen from the photographs. A comparison of visual and optical density rankings showed an 83 percent agreement between them. The visual ranking was, therefore, taken as a sufficiently accurate method of analyzing the photographs.

Preliminary Results

This analysis revealed several types of information, some rather conclusive and the remainder suggestive of phenomena that merit more rigorous

sampling. An evaluation of the near infrared reflectivity of four plant species on six different dates is given in Figure 4. Thirteen plant genera were identified in the photographs and ranked on each of the six dates. On the basis of their phenologies, as evaluated by their changes in near infrared reflectivity, these genera were grouped as follows: Evergreens - Quercus emoryi, Q. oblongifolia, Larrea tridentata, Yucca spp., Opuntia spp., Condalia spathulata, and Nolina microcarpa; Cool season deciduous plants - Prosopis juliflora, Haplopappus tenuisectus, Gutierrezia sarothrae, and Senecio douglasii; Warm season deciduous plants - Bouteloua spp., Acacia constricta. Although this number of species is small in comparison to the total number present in the study area, these species are important in terms of their quantity, contribution to vegetal cover, and their use as character species for identification of vegetation types. They all serve to demonstrate the rationale used for grouping them according to a criterion detectable on Ektachrome Infrared film. Such a grouping activity cannot be conducted without ascertaining its limits of validity. Some of these limits are being probed through studies of composition and structure of the vegetation type. In addition, it is recognized that plant species are present which are very opportunistic and may not lend themselves to the three category classification scheme given above. It is reasonable to expect, in this arid and semi-arid environment, to find plants that leaf-out in response to locally available moisture. Fouqueria splendens is one such plant that may produce leaves following a shower only to lose them as moisture ceases to be available. The plant may leaf-out again following another rain. Prosopis juliflora (mesquite) showed a tendency that may be typical of many of the cool season deciduous plants. The photographs suggested that this plant

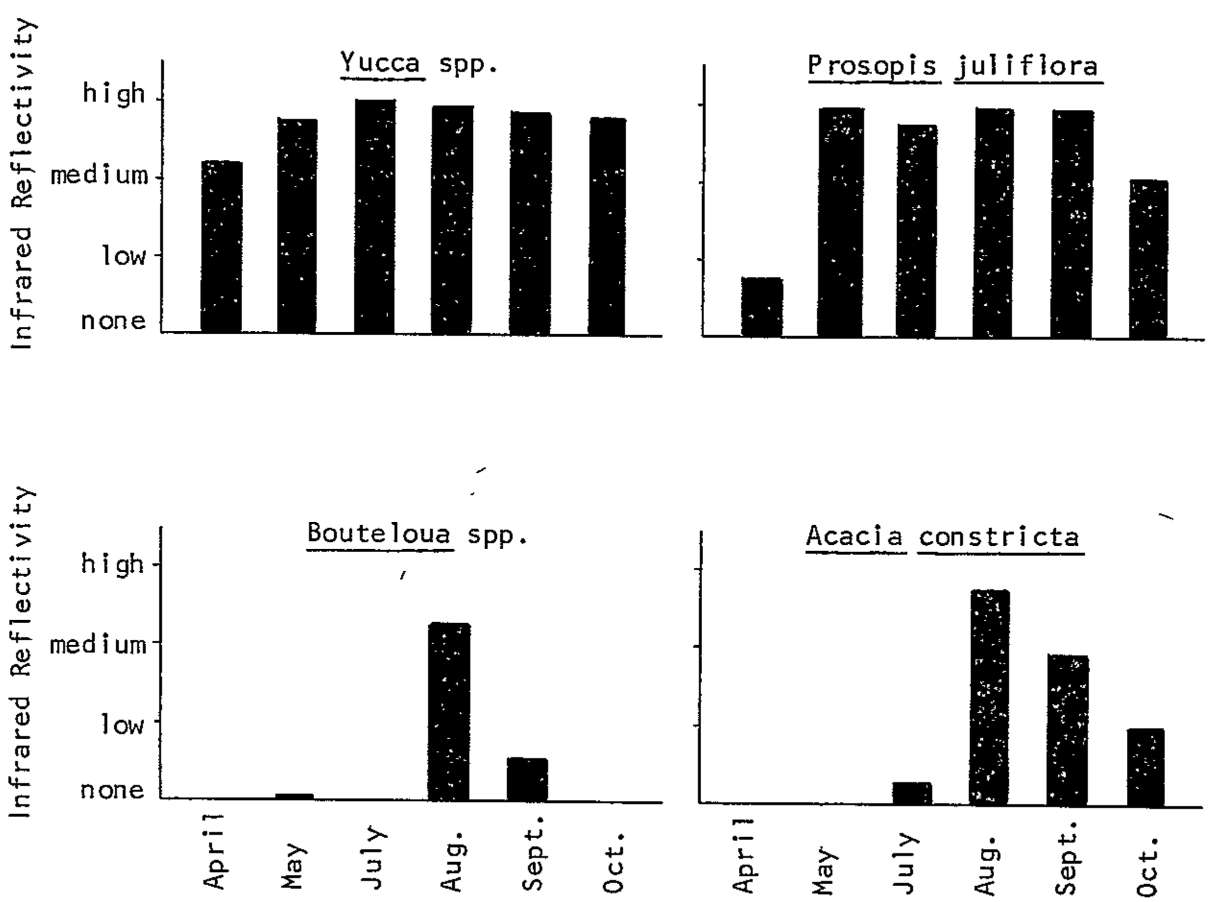


Figure 4. Infrared Reflectivity. This figure shows the results of visually ranking plant species on the basis of their apparent near infrared reflectivity on each of six dates (April 23, May 21 or 22, July 1, August 30, September 30, and October 30). Each Ektachrome Infrared photograph was inspected and the images of the identifiable plants were visually compared and the plants ranked on a scale as having "no" to "high" reflectivity. Similar rankings were obtained by making optical density measurements of the same photographic images in a 15 percent sample of the photographs. There was 83 percent agreement between the results of the two ranking methods; thus, those of the visual method were considered acceptable. The results are given for Yucca spp., an evergreen; mesquite (Prosopis juliflora), a cool season deciduous species; and perennial grasses (Bouteloua species) and whitethorn (Acacia constricta), warm season deciduous species. The relative lengths of time that each species had high near infrared reflectivity and the approximate times when changes in reflectivity occurred are indicated by the graphs. This suggests that Ektachrome Infrared photographic images taken in mid-April, late May, and late August could be compared within dates to rank the subjects on the basis of their relative

Figure 4, (Continued)

differences in near infrared reflectivity; and the rankings compared among dates to reveal the information given in the graphs. In this way, portions of the landscape, corresponding to the photographic images, could be classified as supporting evergreen, cool season deciduous, or warm season deciduous plants.

loses some of its apparent near infrared reflectivity during the dry period of June and early July, and regains that reflectivity following the summer rainy season. This variation may also be related to changing atmospheric conditions. A photographic look at the evergreen oaks suggests that the near infrared reflectivity of these plants also varies through the year, especially in the spring when both new and old leaves are on the tree at the same time.

The perennial grasses of this region produced most of their foliage during and after the summer rains. This concurred with the phenology typical of these grass species. Their infrared reflectivity increased sharply at this time, but was moderated by the old growth remaining from the previous season. Field notes indicated that some of the perennial grasses had green leaves in the spring, but these were over-topped by dried grass material and an infrared record was not obtained from the grasses until after the summer rains. Furthermore, the length of time that the perennial grasses retained their increased infrared reflectivity appeared to be only one and a half months in July, August, and September. At this time of year, the number of clear days per month number only six to eight and obtaining cloud free aerial photography is difficult. An intensely managed Hilaria mutica (tobosa grass) and Sporobolus airoides (alkali sacaton) pasture, which was burned each fall, provided a variation in the typical grassland reflectivity pattern because the burning removed the dried material. The new leaves, developing in the spring, were completely exposed and an infrared record of these plants was obtained on film.

Several photographs taken at one site are used in Figure 5 to show the phenological development of a few common southern Arizona plant species.

April 23, 1969

May 22, 1969

August 30, 1969

September 30, 1969

Figure 5. The Ektachrome Infrared photographs in this figure depict the same scene on four dates. The plants include evergreens (yuccas = Y), cool season deciduous desert shrubs (*Prosopis juliflora* = P), and warm season deciduous species (perennial grasses = G, and *Acacia constricta* = A). In late April, only the yuccas and chaparral species had green foliage and appeared red in the photograph. In late May, *Prosopis juliflora* appeared red and retained this color through the rest of the dates. In late August, the perennial grasses and *Acacia constricta* appeared red. The grasses lost their green foliage faster than the acacia, and the September photograph shows the resulting difference between these two warm season deciduous types. The interpretation of the changes in red color in terms of apparent near infrared reflectivity is given in Figure 4. Compare the photographic images of these plants with the evaluation of this reflectivity.

The four species included in Figure 4 appear in this photographic series.

Between field seasons, plans will be made for continuing this work in greater detail. The results of the work reported here indicate the necessity for more complete information describing the structure of the vegetation units being studied. Additional ground photography will be procured to document changes in near infrared reflectivity of individual plant species and vegetation types. Requests will be made to NASA for RB-57 Ektachrome Infrared aerial photography to be taken at appropriate times during the growing season to determine if these same changes can be detected from vertically above the subjects.

MULTISPECTRAL SIGNATURES OF RANGE ECOSYSTEMS

The imagery being used in this phase of our research are 18 channel multispectral linescan (MSLS) data obtained in 1966 by Oregon State University with some financial support from the Bureau of Land Management. Data acquisition was a cooperative venture with Robert N. Colwell, Forestry Remote Sensing Laboratory, Berkeley, and Victor I. Myers, South Dakota State University, who was at that time with the Agricultural Research Service. We are currently using our 12 channel data from 1,000-foot flight altitude over our Squaw Butte test site near Burns, Oregon, in a vegetational area dominated by sagebrush steppes and western juniper woodlands. The work is being conducted in collaboration with personnel of LARS at Purdue and the Forestry Remote Sensing Laboratory, Berkeley, California.

We are working from a philosophy of prior ecological stratification of test sites into specific vegetation-soil systems as our fundamental ground truth unit. Most other workers in natural resource areas have been concerned with gross geological or broad vegetational classes, not with specific plant communities and vegetation-soil systems as we are. Thus, by working with 1,000 foot data and concerning ourselves with maximum ecological detail in ground truth studies, we should be in a position to determine the limits of applicability of the Michigan MSLS system for range resources applications.

In late July, 1969, Mr. James R. Johnson joined our staff as a half-time Graduate Research Assistant with responsibilities for the analysis of data from this phase of our work.

First run computer printouts for selected portions of the large-scale

imagery at Squaw Butte were received in autumn, 1968. The printouts were mostly half scale with every other remote sensing unit on every other line represented on the printout. Channels chosen for printout were 8 (0.52-0.62 microns), 9 (0.62-0.66), and 11 (0.72-0.80). The printouts included imagery from 23 plant communities and rangeland resource features (Table 6). Training samples of the 23 were located from half scale Channel 9 printouts by comparison of image patterns to panchromatic black and white aerial photography taken at the same time and printed at similar scale. Late in 1968, these sample test areas were coordinate coded and submitted to LARS.

Initial Evaluation

In January, 1969, LARS prepared and returned histograms, spectral plots, and other essential statistics for all 12 channels. It is with this first iteration data that we did the work reported here. Initial evaluation of these statistics provided the following observations:

1. Some histograms and related statistics suggest possible classification of several range resource subjects among those chosen for first iteration evaluation.
2. Some histograms, particularily those for the ROCKLAND training samples tend to be bi- and tri-modal. This probably resulted from obscured inclusions or poor detection of rockland boundaries on the half scale printouts. Some full scale printouts have recently been received from Purdue, and these may enable "cleaning up" of the training samples for a second iteration.
3. The amount of ecological detail recorded in Channel 9 is most encouraging from the standpoint of system resolution in relation to the range problem.

Table 6. Range resource features (plant communities) from the Squaw Butte test strips chosen for analysis of pattern recognition, classification, and automatic recognition techniques as developed by LARS.

Field Designation	Brief Description
Agcr Grazed	Agropyron cristatum (crested wheatgrass) pasture having three intensities of grazing.
Agcr Ungrazed	Crested wheatgrass pasture having uniform appearance and not grazed.
Agcr Ungrazed-Variant	Crested wheatgrass pasture not having a uniform appearance and not grazed.
Agcr With Brush	Crested wheatgrass pasture exhibiting reinvasion by big sagebrush, lightly grazed.
Arar Shield	Artemisia arbuscula (low sagebrush) on upland basalt shields. Surface patterning has pockmark appearance, herbaceous vegetation abundant.
Arar Stringer	Low sagebrush on upland sloping ground. Surface pattern has alternate light and dark streaks in converging herringbone arrangement. Dark areas represent slight depressions (drainages) with higher density of herbaceous cover than in lighter interfluves.
Arca Dense	Artemisia cana (silver sagebrush) in playas, uniformly short and dense with considerable herbaceous vegetation.
Arca Dense/Artr	Silver sagebrush, similar to Arca Dense, but less dense and having patches of Artemisia tridentata (big sagebrush).
Arca Patchy	Silver sagebrush much like Arca Dense but with interspersed areas of barren ground.
Arca Thin	Silver sagebrush similar to Arca Dense but having considerable quantities of barren exposed soil, herbaceous vegetation not abundant.
Artr(wyo) Orwe	Artemisia tridentata ssp. wyomingensis (Wyoming sagebrush) and Oryzopsis webberi (Webber ricegrass) on light textured soil, on gentle sloping upland.
Artr	Big sagebrush having considerable canopy coverage and occupying lowland areas on well drained deep soils.

Table 6. (continued)

Field Designation	Brief Description
Artr Grass	Big sagebrush on low upland with good compliment of herbaceous vegetation.
Artr H-Ants	Big sagebrush similar to Artr Grass but with considerable numbers of ant discs.
Artr M-Ants	Big sagebrush similar to Artr H-Ants, but with fewer ant discs.
Artr Mottled	Big sagebrush similar to Artr but less dense and having an uneven textural appearance created by interspaces occupied by herbaceous vegetation.
Juoc-Arar	*Juniperus occidentalis* (western juniper) along ridges with scattered low sagebrush and herbaceous vegetation.
Juoc-Arar-Artr	Similar to Juoc-Arar but also having big sagebrush.
Juoc-Artr	Similar to Juoc-Arar but big sagebrush is present rather than low sagebrush.
Juoc Dense Arar-Artr	Like Juoc-Arar-Artr but more shrubs.
Rockland	All rocklands consist of broken basalt outcropings, mostly void of vegetation.
Rockland South	Like Rockland but steep and having southerly exposure.
Rockland W-NW	Like Rockland but steep and having west-northwest exposure.

Of the 16 character sets used for displaying relative radiance in the printouts, however, the six representing the lowest radiance do not appear on any of the printouts. Since we are interested in detecting irregular ground surface patterns, a revised apportionment of the character set may be necessary to make optimum improvement in the selection of training samples.

4. Among the 12 bands used, spectral plots within and between most subjects appear highly similar. Although an encouraging amount of discrimination appears possible, few strong cross-overs occur. In cases where discrimination appears unlikely based on tone-shift patterns alone, patterns in the spatial geometry of energy levels may have to be considered in the development of full automatic recognition capability. One possibility is the examination of spatial distance relationships between intrasubject sensing units of comparable energy levels.
5. In examination of photographic printouts for all data, some important crossovers occur in the remaining bands, particularily in the 8-14 micron band. It, thus, appears that if computer access to these bands with registery were possible, we would come closer to fully exploiting the system for range resource application.
6. For two consecutive years, 1968 and 1969, attempts to obtain aerial color infrared photographs for comparative mapping and interpretation were thwarted by poor processing. Satisfactory high-resolution, black and white photography has been obtained, however, and temporarily will have to suffice for comparative interpretation studies.

Preliminary Estimate of Plant Community Recognition Capability

As we examined the individual histograms and attendant data, it was apparent that some of the individual training samples were very well selected, even from the half-scale printouts. Comparison of the individual multispectral plots from these individual samples provided the highpoint of recent progress. It gave an encouraging preliminary estimate of plant community recognition capability. Examples of spectral responses for some range and related resource features are presented in Figures 6, 7, and 8. Where spectral signatures in one or more bands do not overlap at one standard deviation, it is assumed that discrimination capability exists.

Potential separation of three grazing intensities on a small crested wheatgrass pasture is shown in Figure 6. Nearly all bands appear to separate lightest from heaviest use. In channels 2 and 8, lightest use can be discriminated from intermediate or heaviest use, but separation of intermediate use from heaviest use appears unlikely as no separation in relative reflectance occurs for these two intensities in any band.

Figure 7 shows spectral responses of three plant communities, all having the same major plant constituent, silver sagebrush (Arca). Even though these communities are similar, discrimination is likely. "Arca Thin" is clearly separated from "Arca Dense" and from a complex mixture of dense silver and big sagebrush (Arca Dense/Artr) in most bands. In Channel 12, "Arca Dense" separates from "Arca Thin" and from "Arca Dense/Artr". If these indications hold up, it is encouraging that separations among these communities dominated by the same species may be possible.

Figure 8 represents a case of three disimilar communities, based on composition, but because two of them display highly variable spectral responses, no discrimination appears possible among the three. High variance

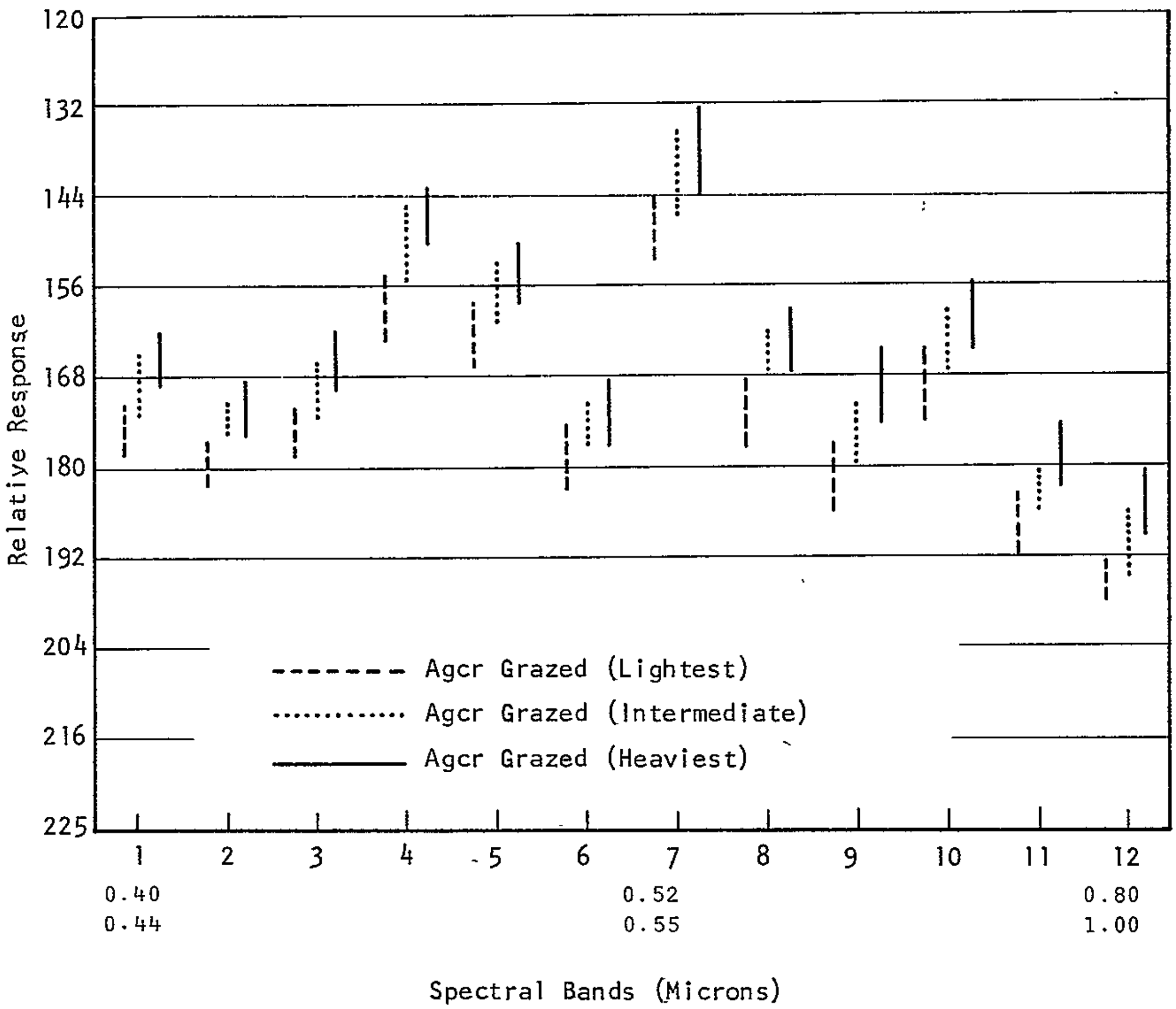


Figure 6. Spectral plot comparison prepared from first iteration printout of training samples. Relative response values are from a crested wheatgrass pasture with three grazing intensities. Some potential of grazing intensity identification appears probable.

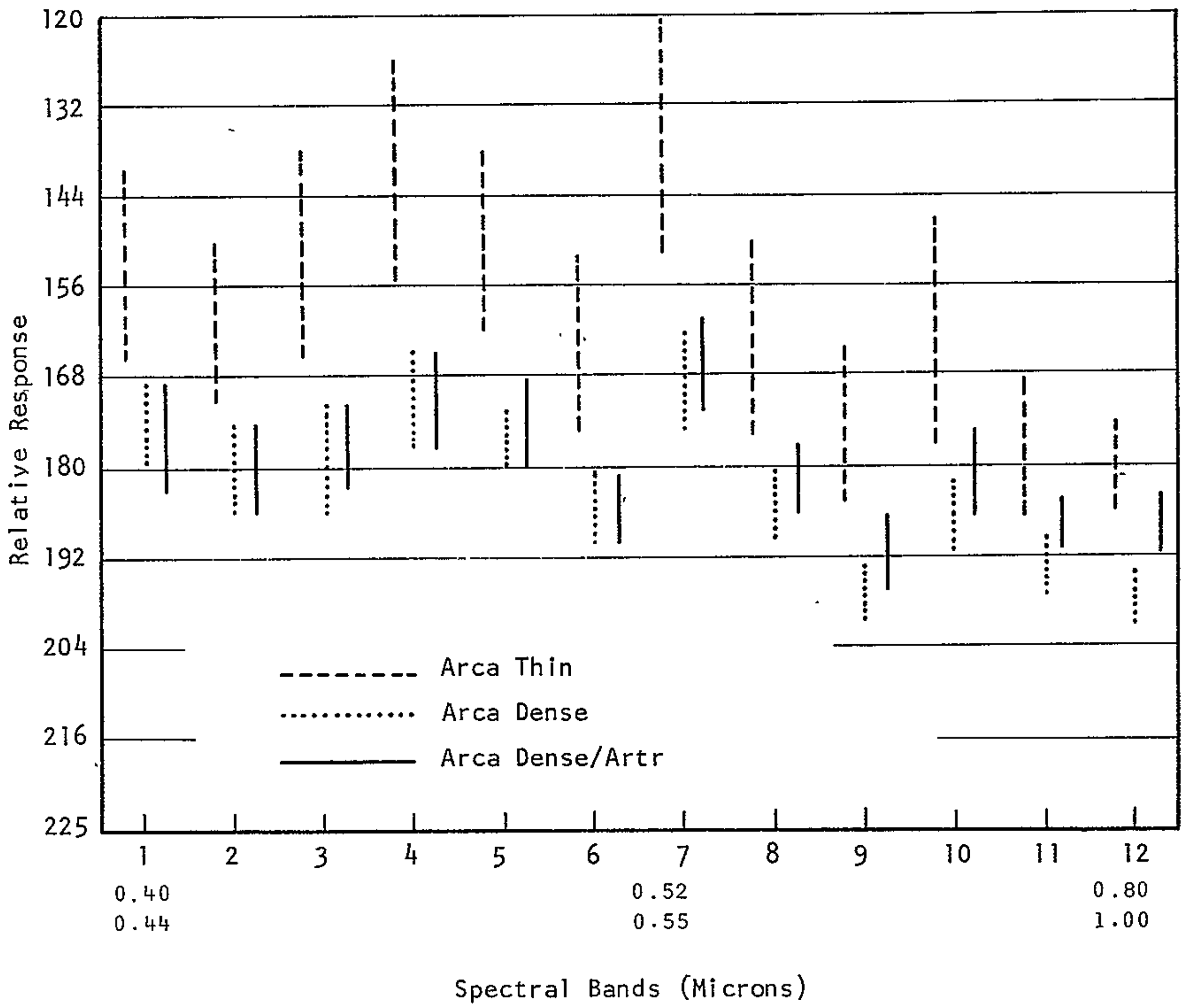


Figure 7. Spectral plot comparison prepared from first iteration printouts of training samples. Three similar silver sagebrush communities having a good likelihood of discrimination are shown.

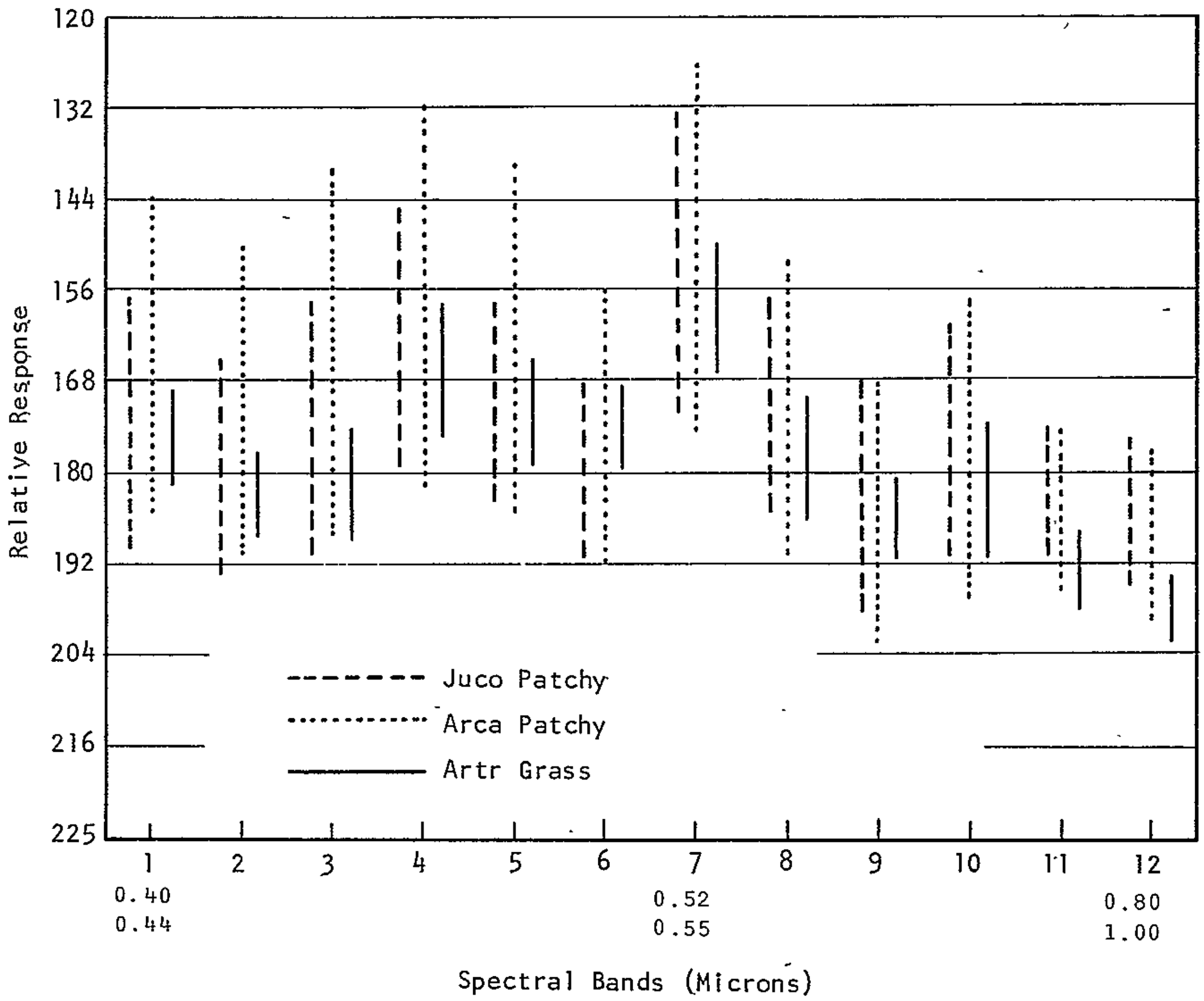


Figure 8. Spectral plot comparison prepared from first iteration printouts of training samples. These three dissimilar communities, with wide relative radiances, offer little promise of discrimination without further refinement.

in spectral responses such as displayed by "Juco Mixed" and "Arcá Patchy" suggest complex reflectance patterns within the communities. Part of the problem in both of these instances may be poor training samples because of high variability within the respective vegetation areas.

In order to further establish likelihood of discrimination, the spectral signature of each range resource feature examined was compared with all other signatures. The results are tabulated in a matrix (Table 7). Again, discrimination was considered possible (+) when a separation in relative reflectance was observed in any channel. If considerable overlap occurred for all channels, discrimination was scored not possible (-). If only slight overlap in relative reflectance occurred (o), this too was noted. In all of the 231 inter-feature comparisons that are possible, discrimination potential exists for 116 (+), some discrimination may be possible in 24 (o), and discrimination appears unlikely in 91 (-).

Completion of these MSLS studies may provide some useful range ecosystem signature records and analytical capability of value in ERTS-A studies. ERTS coverage has been requested to include this study area.

Table 7. A likelihood of discrimination matrix of range resource features developed from first iteration spectral plot comparisons. The symbols used suggest: Discrimination in some or all channels (+), discrimination may be possible (o), and discrimination appears unlikely (-) without further refinement.

Field Designation (Ecosystem Name)	Artr	Artr Bottom	Artr Grass	Artr H-Ants	Artr M-Ants	Artr Mottled	Artr (wyo) Orwe	Arar Stringer	Arar Shield	Arca Dense	Arca Dense/Artr	Arca Patchy	Arca Thin	Agcr Grazed	Agcr Ungrazed	Juoc-Arar	Juoc-Artr	Juoc Mixed	Rockland	Rockland So. A	Rockland So. B	Rockland W-NW
Artr	-																					
Artr Bottom	-	-																				
Artr Grass	+	-	-																			
Artr H-Ants	-	o	-	o																		
Artr M-Ants	-	-	-	-	-																	
Artr Mottled	-	+	o	o	o	-																
Artr (wyo) Orwe	+	+	+	o	+	-	-															
Arar Stringer	-	o	+	o	o	-	-	-														
Arar Shield	-	-	-	-	-	o	+	+	-													
Arca Dense	o	-	-	-	o	o	+	+	-	-												
Arca Dense/Artr	-	-	+	o	o	o	+	o	+	+	-											
Arca Patchy	-	-	-	-	-	-	-	-	-	-	-	-										
Arca Thin	+	+	+	+	+	-	-	-	+	+	+	-	-									
Agcr Grazed	+	+	+	+	+	-	-	o	+	+	+	-	-	+								
Agcr Ungrazed	+	+	+	o	-	-	+	-	+	+	+	-	+	+	-							
Juoc-Arar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
Juoc-Artr	-	-	o	-	-	-	+	-	-	-	-	-	o	+	o	-	-					
Juoc Mixed	-	-	o	o	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Rockland	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-			
Rockland So. A	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-		
Rockland So. B	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	
Rockland W-NW	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	o	-	-	-

116 (+) discrimination in some or all channels
91 (-) no discrimination in any channel
24 (o) discrimination may be possible

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APPENDIX A. Sample Legend Expressions for Rapid Ground-Truth Recording. This legend notation system can be rapidly and easily used from either the ground or low-flying aircraft once the vegetational characteristics of the region and legend are well-learned by the observer.

Legend Examples

$$\frac{2.2\ B^{5}S^{3}_{dl}}{7.5YR}$$

$$\frac{3.6\ B^{3}H^{2}_{dl}C^{1}_{gl}}{5YR/7.5YR}$$

$$\frac{3.8\ H^{4-6}_{dl}S^{1}_{dl}}{10YR}$$

Legend Components and Key

Numerical Descriptor of Vegetation (See Appendix B-3 for key)

These examples are:
2.2 = Whitethorn, Creosote Bush, Tarbush
3.6 = Mesquite Grassland
3.8 = Pure Grass Bottoms

Dominant Ground Surface Feature

T = Trees
S = Tall Shrubs, > 1 meter
L = Low Shrubs and "Halfshrubs"
C = Cacti and related forms
H = Herbs, Grasses and Forbs
B = Bare Mineral Soil
R = Rock

Cover Classes for Above Features

1 = 0+ - 5 percent
2 = 5+ - 25 percent
3 = 25+ - 50 percent
4 = 50+ - 75 percent
5 = 75+ - 95 percent
6 = 95+ - 100 percent

Phenology

g = green vegetation
d = leafless and photosynthetically inactive
m = leafy but mature and photosynthetically inactive

Utilization

h = Heavy use by grazing animals
m = Moderate use, considerable growth remaining
l = Light use, hardly or not perceptible

Soil Surface Color (Munsell Hue)

5YR
7.5YR
10YR
Others as needed

APPENDIX B-1. Symbolic Mapping Legend.

PRIMARY VEGETATIONAL AND LAND-USE LEGEND

Symbol	Physiognomic Type or Land Use
10.	"Barren" lands (Less than 10 percent vegetated)
20.	True Deserts (Prominent plants scattered; non-vegetated soil surface is dominant landscape feature)
30.	Shrub/Scrub Lands (Soil surface mostly obscured, shrubs most prominent vegetational feature)
40.	Steppes (Herbs most prominent vegetational feature)
50.	Savannas
60.	Forested and Wooded Lands (Arborescent)
70.	Alpine-Tundra/Arctic-Tundra
80.	Vegetation of Aquatic Environments
90.	Water Resources (Free water surfaces of mapable size)
100.	Agricultural Land
200.	Urban and Industrial Lands (Including transportational facilities of mapable dimensions)

APPENDIX B-2. Symbolic Mapping Legend.

BARREN LAND TYPES

Symbol	Type
10.	Barren Land (<10 percent vegetated)
11.	Playas
11.1	Flats, Uninterrupted
11.2	Interspersed with Dunes
11.3	Interspersed with Occasional Vegetated Hummocks
12.	Sand Dunes
13.	Rockland
13.1	Bedrock Outcrops/Rimrocks
13.2	Boulder Fields
13.3	Glacial Detritus
13.4	Lava Flow
13.5	Rock Nets/Stripes
13.6	Talus/Colluvium
14.	Upland Barrens (On terraces, plateaus, and undulating lands; not rockland)
14.1	"Badlands", Silty/Clayey
14.2	Land Slides/Fault Scarps/Erosional Escarpments
14.3	Slicks
15.	Shore Lines and Beaches
16.	Made-Lands (Raw land resulting from human activity)
16.1	Cuts and Fills, Non-mining
16.2	Mining Activity

APPENDIX B-3. Symbolic Mapping Legend. The first iteration of a workable vegetation legend for the Tucson-Willcox-Ft. Huachuca triangle of southeastern Arizona.

SECONDARY VEGETATIONAL LEGEND

Symbol	Vegetational Descriptors
1.0	Cactus-Microphyll Desert
1.1	Creosote Bush with very sparse ground cover
1.2	Mesquite, Creosote Bush, Burroweed
1.3	Whitethorn, Prickly Pear, Ocotillo, sparse herbs
1.4	Saguaro, Palo Verde, Brittle-bush, Bur-sage
2.0	Microphyll-Thorn Scrub Desert
2.1	Whitethorn, Mesquite, devoid of herbs
2.2	Whitethorn, Creosote Bush, Tarbush
2.3	Mesquite bosques and drainage ways
2.4	Mortonia, Whitethorn
2.5	Sumac, Whitethorn, Nolina, Soaptree Yucca, Zinnia
2.6	Whitethorn, Wright Lippia, Ocotillo
3.0	Steppe
3.1	Bunch/Sodgrass steppe (pure grassland)
3.2	Soaptree Yucca grassland
3.3	Nolina grassland
3.4	Mesquite, Burroweed grassland
3.5	Creosote Bush, Whitethorn, Ocotillo grassland
3.6	Mesquite grassland
3.7	Creosote Bush grassland
3.8	Pure grass bottoms
4.0	Oak/Juniper Savanna
4.1	Oak grassland savanna
4.2	Juniper grassland savanna
5.0	Woodland and/or Chaparral
5.1	Oak woodland
5.2	Juniper woodland
5.3	Pinyon pine woodland
5.4	Chaparral brushland
6.0	Montane Forests
6.1	Ponderosa pine dominant
6.2	Douglas fir dominant
6.3	Engelmann spruce dominant

NOTE: In the next iteration, this legend will be modified to make it more applicable outside the above triangle area. The organization and classes will be changed to fit within the primary classes in Appendix B-1 and the decimal point will be dropped so that two digits of this nature will become the secondary classifiers in the first two decimals to the left of the decimal point, thus, __.00.

APPENDIX B-4. Symbolic Mapping Legend.

WATER RESOURCES LEGEND

Symbol	Type of Water Resource
90.	Water Resources (Free water surfaces of mapable size)
91.	Lakes
91.1	Natural
91.2	Artificial/Enlarged
92.	Water Courses, Permanent
92.1	Rivers and Creeks
92.2	Canals and Ditches
93.	Bays and Estuaries
94.	Oceans and Seas

APPENDIX B-5. Symbolic Mapping Legend.

AGRICULTURAL LAND

Symbol	Class of Agricultural Land
100.	Agricultural Land
110.	Green and Growing Crops
120.	Dormant/Harvested Aftermath
130.	Burned Aftermath
140.	Orchards/Vineyard/Cultured Forests
150.	Fallow/Tilled/Seeded Land (Not growing)
190.	Abandoned Land
191.	Revegetating Land
192.	Erosional Wasteland
	Uniform Subclasses for 110./120./130.
__1.	Hay/Pasture
__2.	Cereals (Excluding Corn and Sorghums)
__3.	Row Crops (Including Corn and Sorghums)

NOTE: Broad classes of specific crops are indicated under each of the appropriate primary or secondary classes by the 1/10th and 1/100th decimal, thus: ___.00; and the specific crop is indicated by one or more of the ___.__000 digits progressing toward finer classes (species, variety, etc.) with each progressive digit to the right. Obviously, the farthest digits to the right would tend to require very large-scale imagery, varietally specific signatures, or ground determination.

APPENDIX B-6. Symbolic Mapping Legend.

URBAN AND INDUSTRIAL LANDS

Symbol	Type of Urban or Industrial Land
200.	Urban and Industrial Lands (Including transportational facilities of mapable dimensions)
210.	Cities and Megalopolis
211.	Business Districts and Shopping Centers
212.	Old Urban Residence
213.	New Urban Residence
214.	Small-acreage Suburban Residence
215.	Developing Subdivisions and Small-acreage Suburb
220.	Towns and Villages
230.	Industrial and Manufacturing
290.	Transportation Developments (Surface)
291.	Navigable Rivers and Canals
292.	Major Freeways, Multiple-lane
293.	Hard Surfaced Highways, 2/3-lane
294.	Unsurfaced roads, graded
295.	Unsurfaced roads, ungraded
296.	Railroads

NOTE: Ability to use the designators in Class 290. obviously depends on the scale and resolution of the imaging system.

APPENDIX C-1. Macrorelief Classes Especially Useful in Mapping from Space Photography.

Symbol	Class Name and Description
1	Flat lands: Very gentle slopes; generally under 10 percent; extensive smooth slopes; if interrupted by slopes in excess of 10 percent, these are usually short and represent abrupt changes between two general base levels; land may be infrequently dissected by narrow, deep and steep-sided drainages. The dominant aspect is one of level land.
2	Undulating and Rolling land: Moderate but smooth slopes in simple systems of slopes and drainages. Slopes are predominantly over 10 percent. The general aspect is one of slopes merging smoothly into one another. The troughs in the relief pattern tend to return to the same base level (unless rock strata are strongly tilted) rather than for slopes to build upon slopes as in hilly areas.
3	Hilly lands: Moderate to steep slopes, still tend to merge smoothly from pitch to pitch. Ridges tend to be rounded but the relief pattern is more broken and irregular than Class 2. Troughs do not tend to return to a common base level. A moderately complex system of major and minor ridges and swales. Drainage patterns tend to consist of major and minor drainages with the latter extending to higher levels in primary, secondary and even tertiary patterns; but with the general contour one of smooth relief changes. May include escarpments and cliffs depending on rock stratification but these are minor components of the landscape.
4	Mountainous lands: Moderate to very steep slopes with ridge, slope and drainage patterns that give a more rugged appearance to the landscape and which build higher and higher in a very complex system of major and minor drainages superimposed one on the other as elevations increase in normally abrupt and steep gradients. Excarpments and abrupt changes are more common than the generally smooth and blending contours that typify hilly lands. A very complex system of ridge on ridge with comparably complex drainage systems. Generally sharp ridgelines and predominantly steep slopes are useful criteria of mountainous areas.

APPENDIX C-2. Ecologically Relevant Physical Features of the Landscape.

LANDFORM FEATURES

Symbol	Ecologically Relevant Physical Feature
A	Bayous, Swamps. Tide-flats, and Deltas (vegetated)
B	Bottomland, undesignated or unclassified as to type
Ba	Stringer Bottom, narrow but not found in young, "V" shaped canyons and drainages
Bb	Valley Bottom; wide, including floodplains or "first Bottoms"
Bc	Basin, not seasonally ponded
Bd	Basin, seasonally ponded
C	Alluvial plains, fans and terraces
Ca	Bajadas and Fans
Cb	Terraces
Cc	River
Cd	Lake
Ce	Marine
D	Level to Rolling Uplands, Benches, Mesas, and Plateaus
E	Dunes, Sandhills, or Beachridges
F	Slopes--Ecologically significant by virtue of a change in vegetation and/or soil with the change in slope
Fe	Exposed slopes (to prevailing winds and insolation, normally W, SW, S, SE and sometimes E aspects in northern hemisphere, opposite in southern hemisphere)
Fp	Protected slopes (from prevailing winds and insolation, normally NW, N, NE and sometimes E aspect in northern hemisphere, opposite in southern hemisphere)
	If slopes are ecologically steep in that they support a different vegetation with the ecotone corresponding to the slope change from moderate to steep, add a designator "s" to the symbol (e.g., Fes = Exposed steep slope)

APPENDIX C-2, (Continued)

Symbol	Ecologically Relevant Physical Feature
G	Patterned Ground
Ga	Biscuitland Complex
Gb	Ridge-Swale Complex
Gc	Pittedland Complex
H	Scabland and/or Rockland; vegetated, not barren
Hd	On Relevant Landform Feature "D"
Hf	On Relevant Landform Feature "F"
I	Ridge-top, convex portion of ridge above tangent with slope-regardless of relative elevation; supports unique vegetation with ecotone more or less at point of tangency; ridge not broad enough to form class "D" feature
	Canyon, Ravine or Arroyo; narrow and deep, young erosionally "V" shaped except arroyos in some soils where they are narrow, vertically sided and "U" shaped.

On Relevant Physical Features "C", "E", and "F", position on slope may be relevant and of ecological significance. When so, as indicated by a change in image characteristics or in vegetation or soils, indicate by subscript "u", "c", and "l" to designate upper 1/3, center 1/3, and lower 1/3 of slope.